Stochastic Optimal Control for Powered Descent Guidance

Completed Technology Project (2017 - 2021)

Project Introduction

Entry, descent, and landing (EDL) is the process of a spacecraft entering a planet's atmosphere, decelerating from orbit, and descending to a safe landing on the planet's surface. Extreme heat, high aerodynamic loads, difficulties in communication and localization, and small guidance margins characterize EDL. NASA Technology Area (TA) 9.2.6 (Large Divert Guidance) identifies a guarantee on satisfaction of constraints, optimal or near-optimal fuel consumption, and on-board computational feasibility as necessary components of a next generation solution. To date, the most accurate EDL procedure was performed on the MSL mission with a landing target ellipse of 10 km while technology requirements (TA 9.2.6) call out a landing ellipse requirement on the order of 1 km. State-of-the-art descent guidance methods rely on deterministic formulations of spacecraft dynamics, and hence any statement of fuel-consumption optimality can only be made with respect to a deterministic model. Since there exist unmodeled disturbances in practical application, we cannot make strong statements regarding optimality when applying deterministic controllers in real scenarios. For a certain class of systems, controllers designed using stochastic optimal control theory have been shown to outperform classical controllers. Furthermore, recent developments in stochastic optimal control theory have shown that linear time-varying systems with Weiner process noise can be steered from initial to final state mean and covariance. While not yet extended to EDL, these developments in stochastic optimal control theory may be relevant to construction of better performing descent guidance systems. This proposed research will constitute an analysis of stochastic process theory as applied to the descent guidance problem, with the expectation of improved fuel performance. Additionally, stochastic methods provide explicit definition of state covariance, hence allowing a system designer to consider trades of covariance bounds on fuel cost, potentially leading to improved system performance. Expected products of this research will include publications introducing extensions to stochastic control theory for cases relevant to powered descent guidance. This work will also produce simulation results comparing performance of deterministic and stochastic controllers.

Anticipated Benefits

This proposed research has the potential to improve fuel performance and lead to improved system performance. Expected products of this research will include publications introducing extensions to stochastic control theory for cases relevant to powered descent guidance. This work will also produce simulation results comparing performance of deterministic and stochastic controllers.

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Table of Contents

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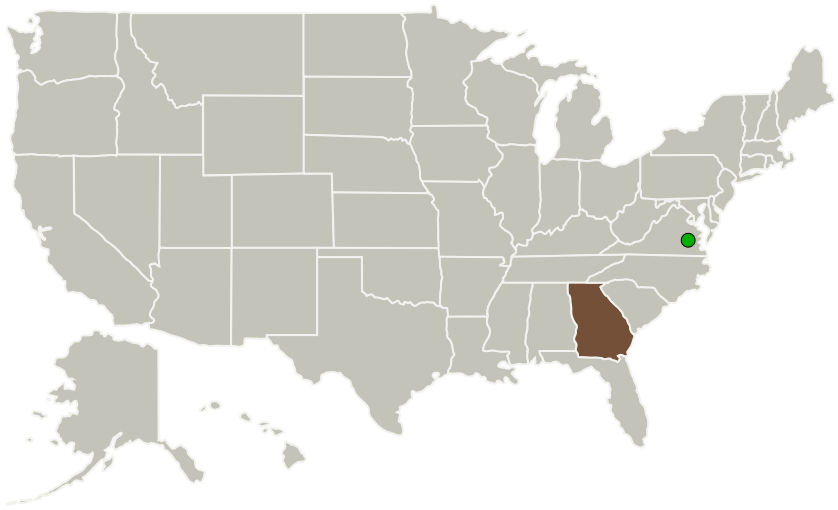
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Georgia Institute of Technology-Main Campus(GA Tech)	Lead Organization	Academia	Atlanta, Georgia
Langley Research Center(LaRC)	Supporting Organization	NASA Center	Hampton, Virginia

Primary U.S. Work Locations
Georgia

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Georgia Institute of Technology-Main Campus (GA Tech)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Panagiotis Tsiotras

Co-Investigator:

Jack Ridderhof

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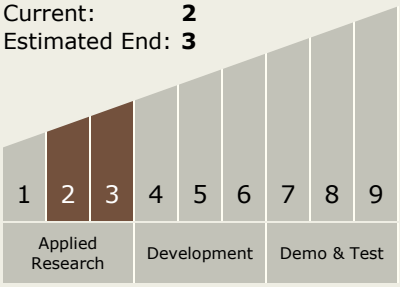
Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  - TX09.4 Vehicle Systems
    - TX09.4.7 Guidance, Navigation and Control (GN&C) for EDL

Target Destination

Foundational Knowledge